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Fast diffusion of Si and O in San Carlos olivine under hydrous conditions

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Water has a strong influence on the physical and chemical properties of minerals and melts- from depressing the melting temperature of rocks, through enhancing deformation rates, to increasing the melt transport rates. However, little is known about the influence of water on the rates and mechanisms of diffusion of elements in mantle minerals. We are carrying out piston cylinder experiments to determine the diffusion rates of Si and O in San Carlos olivine (~Fo_{90}) under water-bearing conditions. The experiments were performed using a cell assembly of talc-pyrophyllite and graphite or AuPd capsules, at 2 GPa and between 1350 to 1300 °C. As a source of water we used brucite powder although in most runs water was not directly added but the talc of the cell assembly acted as a source of water. The diffusion couples consisted of olivine cylinders coated with a thin film of the same olivine composition but enriched in ^{29}Si and ^{18}O [1]. Isotopic gradients were measured using the depth profiling mode in a Cameca IMS-4f ion microprobe (University of Edinburgh, UK). FTIR spectra of the olivines after the experiments shows that their water content is higher than that of the starting olivines. We found that the diffusion rate of Si is ~ 3 orders of magnitude higher than that obtained by [1] at 1 atmosphere and dry conditions. The diffusion rate of O is also higher but only by ~ 1 order of magnitude. Similar effects have also been found for the diffusion rates of Si and O in feldspars and quartz by other workers. The enhanced diffusion rates of Si and O in olivine at water-bearing conditions are also consistent with the faster deformation creep rate data of olivine aggregates obtained under 'wet' conditions. The fact that the diffusion rate of Si is more affected by the presence of water than that of O agrees with point defect models that suggest that diffusion of Si is the key atomic step in the deformation of olivine. These results should prove very useful for describing the rheological behavior and convection modes of the mantle wedge above subduction-zones.

References

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Effect of P-T and composition on dihedral angles in fluid-bearing mantle minerals and fluid migration in the Earth's interior

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The dihedral angle provides useful information to determine the connectivity and distribution of fluid phases in a polycrystalline material, and is known to be a function of pressure (P), temperature (T) and compositions of crystal and fluid phase. This information is needed to characterize the chemical and physical evolution of the Earth, because the connectivity of aqueous fluid affects chemical transport and bulk-rock physical properties of mantle materials.

In the olivine-H_2O system, a negative dependence of dihedral angles on P-T has been observed [1], due to the increase in olivine solubility in aqueous fluid with increasing P-T. In the system eclogite-H_2O, however, the dihedral angle at cpx-cpx-fluid junctions does not vary in the P-T range investigated [2] even though Watson and Lupulescu [3] reported that the dihedral angle in cpx-H_2O system was positively correlated with Mg# of cpx. The lack of P-T dependence of the dihedral angle at cpx-cpx-fluid junctions in eclogite-H_2O system could be explained by the effect of Mg# and P-T, because both cpx solubility in aqueous fluid and Mg# of cpx in eclogite-H_2O system increased with increasing P-T.

For the better understanding of the effect of P-T and composition on dihedral angles, we have measured dihedral angles in olivine H_2O system with changing Mg# of olivine at 1 GPa and 1000ºC. The angles showed a slight positive correlation with Mg# of olivine, similar to the cpx-H_2O system [3]. These results suggest that the possible fluid flow from the deeper and Fe-rich fertile mantle under hydrostatic conditions could be stagnant at the basement of the depleted mantle such as cratonic lithosphere because of the change in the fluid permeability.

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